ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

PROJECT NO. 6 - VISION IN TANKS

Partial Report

On

Visual Requirements, Characteristics and Limitations of Present Visual Devices in Tanks and Means for Improving Sighting Telescopes and Periscopes

Project No. 6 (6-1, 6-2, 6-4) January 23, 1943

ARMORED FORCE MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Projects No. 6-1, 6-2, 6-4
File No. 413-74

January 23, 1943

Partial Report On

VISUAL REQUIREMENTS, CHARACTERISTICS AND LIMITATIONS OF PRESENT VISUAL DEVICES IN TANKS AND MEANS FOR IMPROVING SIGHTING TELESCOPES AND PERISCOPES

1. PROJECT: No. 6, Sub-projects No. 6-1, 6-2 and 6-4, Requirements, Characteristics and Limitations of Present Visual Devices and Means for Improving Sighting Telescopes and Periscopes.

a. Authority: Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, File 400.112/6 GNOHD, dated September 24, 1942.

b. Purpose: To determine the limitations of present periscopes and sighting telescopes and to recommend means for improving them.

2. DISCUSSION:

a. Problems involved have been studied from the standpoint of fundamental principles, by review of new findings of research groups, and by examination and test of existing equipment.

b. The practical needs have been established by study of reports from combat areas and British communications, from experience on the range and on maneuvers, and by analysis of functional requirements of the task.

c. Technical procedures have been investigated in respect to inherent limitations of optical design, the restrictions imposed by the design of the tank, and the limits inherent to the problem.

d. The practical steps by which improvement can be made have been investigated in respect to availability of material, manufacturing facilities, and facilities for design and pilot production.

e. Recommendations for action are submitted in order of urgency of need. The steps required to carry out the recommendations are indicated.

f. Pertinent facts and details are given in appendices I, II and III.

3. CONCLUSIONS:

a. The present periscopic sight has serious limitations.

b. The proposed telescopic sights (M50 series) do not achieve sufficient improvement.

c. The mechanical provisions for sight mounting, linkage and adjustment by bore sighting are not adequate.

d. Sufficient consideration has not been given to sight placement in relation to the gunners posture in tank design.

4. RECOMMENDATIONS:

a. That the Armored Force carry out acceptance tests on pilot models of sights that are to be issued for armored vehicles. These tests to comprise:

(1) Gunnery testing by the Armored Force Board.

(2) Mechanical suitability, linkage and service durability by the Armored Force Board.

(3) Optical adequacy by the Armored Force Medical Research Laboratory.

b. That a better corrected optical system be substituted in the M50 series sight production at the earliest possible time--securing adequate flatness of field and resolving power.

c. That in the interim, assembly procedures be modified to insure maximum effectiveness; especially a compromise focal setting such that the effective focus is for infinity and aberrations can be offset by positive accommodation.

d. That the bore sight mark on reticles for low velocity guns be raised as much as practicable to bring a greater portion of the pattern required for greater ranges into the useful field.

e. That every effort be made to make the lines and dots in the reticle as fine as compatible with good visibility and that the refractive border around the lines and dots be kept to a minimum such that the entire obscuring width is held to specified width tolerance.

f. That the project to provide half-wave surfacing or blooming of the interior surfaces be expedited because of the difficulty with veiling haze.

g. That a sight mount be developed which will keep the sight in adjustment while going cross country. The best sight is no good if its mount will not hold it in adjustment; the present mounts for these sights are unsatisfactory.

h. That mechanical linkage and mounting of the periscope sight also be revised to secure adequate precision and ruggedness.

i. That two (2) periscopic dual sights, of the characteristics described in the accompanying drawing (Appendix II 2a and Inclosure 1) be developed, fabricated and shipped to Fort Knox, Kentucky, for test.

j. That three (3) telescopic sights of the characteristics given in the attached drawing (Appendix II 2c and Inclosure 3) be developed and manufactured and sent to Fort Knox, Kentucky, for test.

Prepared by: Major F. S. Brackett, Sn C.

APPROVED Willard Machle
WILLARD MACHLE
Lt. Col., Medical Corps
Commanding

3 Inclosures
#1 - Periscopic Dual Sight (Drawing)
#2 - Periscope Holder (Drawing)
#3 - Telescopic Sight (Drawing)

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(Outline)

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   c. Considerations Governing Optical Design
   d. Conditions of Fire

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      2) For Long Range
      3) Reserve or Compromise Sight
   b. General

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   b. Coaxial Telescopic Sight

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APPENDIX I

1. CHOICE OF SIGHT PROPERTIES

a. Tactical considerations -

The ability to see, is such a prime necessity of tank fighting, that jockeying for advantage in seeing has become an important aspect of tank strategy, just as it is in air and naval combat. The requirements on optical instruments are most exacting under the following conditions:

1) Low light intensity
2) Low contrast of target
3) Facing glare - low sun or bright sky, especially with poorly illuminated targets.

The enemy has been quick to realize his optical advantage and choose, whenever possible, time and position for contact where one or more of these conditions are operative in his favor.

b. Characteristics of Vision -

Facts concerning minimum visibility which dictate the steps required to overcome these conditions are as follows:

1) Loss of Illumination may be offset by magnification since -

   A larger object of the same contrast can be more easily seen than a smaller object. Thus it follows that -

   Three times magnification offsets a ten times loss of illumination at high contrast or a hundred times loss of illumination at low contrast.

   Eight times magnification offsets a hundred times loss of illumination at high contrast and about five thousand times loss at low contrast.

2) Magnification also overcomes loss of contrast for example, from eight to twenty times magnification may be required to offset a ten fold loss of contrast.

3) Loss of contrast is far more serious than loss of illumination for example, halving the contrast may be equivalent to as much as a ten times loss of illumination.

   Reducing the contrast 90% may be equivalent to a hundred times loss of illumination in the higher contrast range or even ten thousand times loss of illumination in the lower contrast range.

c. Considerations governing Optical design are:

1) The optical parts - lenses, prisms, plates, etc., reduce contrast by flare and veiling haze and reduce the advantage of magnification. Thus

in a telescopic sight (lens inversion) there are 14 to 18 surfaces each contributing by reflection and scattering to the veiling haze. This may, under conditions of low light intensity, low contrast or glare, entirely obliterate the advantage of 3x magnification. ~~The~~ fact it may render the sight less effective than ordinary unaided vision. More specifically - veiling haze (loss of contrast) depends upon -

a) Number of surfaces
b) Quality of surfaces
c) Quality of refracting material
d) Wall reflection - diaphragming, etc.
e) Not on amount of magnification - loss of contrast may be as much in unit power as in eight power.

2) Veiling haze is reduced by -

a) Blooming the surfaces and so cutting down reflection
b) Careful design and placement of diaphragms
c) Use of materials of high quality
d) Fine quality of optical polishing, etc.

3) Magnification is limited by -

a) Field requirements -

It has been the practice in sight design to assume that the apparent field (as it appears to the eye) could not exceed 36° or 37°. Thus since magnification x true field = apparent field (taking a 4 power sight for example):

$$4 \times 9^\circ = 36^\circ$$

the possible true field would therefore be 9° since it is agreed that 8° is minimum due to the target escaping the field after firing, etc., and that 12° is desirable, a power greater than 4x would not be achievable under former restrictions.

Telescopic sights (lens inversion) of good quality have now been produced up to 62.5° apparent field. (See German 2.5x power - 25° true field or mock up in Laboratory 3x power - 20° true field). Prismatic sights of even better quality have been made up to 72° - thus it is optically possible to obtain a 6x power with 12° true field.

b) Motion of Image -

When unit power sight is moved the image remains stationary. A glass of M power causes the image to move by M minus 1 times the angular motion of the glass. Thus a 3x power causes the image to move by 2x the angular motion of the instrument; while a 10x power introduces a motion nine times greater than the motion of the glass. Hence, it is common experience that more than a 6x power binocular cannot be used by most people because of muscular tremor.

Engine disturbance of vehicle may set a limit to magnification for rigidly mounted instruments (in aircraft 6 power sights have to be mounted in vibration absorbing devices). Clearly, when the tank is in motion, very little magnification can be used because of image motion.

4) Light gathering power depends upon -

a) Exit pupil. The dark-adapted eye can use up to 7.5 mm. Since magnification x Exit pupil = Entrance pupil, the exact pupil influences the diameter of the objective and the minimum armor perforation. Thus for 6x power: 6 x 7.5 = 45 mm or about 1-3/4" armor perforation. Moreover the opening in the armor must flare in order not to reduce the field or exit pupil off the optical axis.

b) Transmission. Chief factors are:

1. Loss by reflection (dependent upon the number of surfaces and whether or not bloomed).
2. Amount of glass in path and quality of glass.

5) Prismatic Sight vs. Telescopic (lens-erecting) Sight

a) A prismatic sight is better than a telescope since the former offers: Less reduction contrast (less surfaces with, less veiling haze, flare, etc.). Greater possible apparent field and so permits higher magnification. Greater transmission (less surface reflection). Better definition and quality.

b) The choice between a telescopic and a prismatic sight depends on the general tank layout. A telescopic sight is long and straight. A favorable length is from 17" to 25", whereas the prismatic sight is short and offset--thus may be from 4" to 12" long and can readily be made periscopic.

d. Conditions of Fire

1) Tank operations are of two distinct types. In the first or close - infire targets may be moving rapidly in the field of view and/or the tank may be on the move. Targets appear large and rapidity of fire is at a premium. In the second type or long-distance fire objects, though possibly moving, do not move rapidly in the field and the tank is stationary. Targets appear small and are difficult to see but there is more time for careful aim.

2) Optical Requirements are very different for the two types of fire

a) Close-in fire requires:

1. Large field - so as not to lose moving targets and to be aware of rapid changes affecting direction of fire.

2. Minimum of magnification because there is disturbance from motion of tank.
3. Long eye-relief to take up shocks of motion and movements of the head.
4. Minimal restriction of eye position since neither motion or time permits search for a restricted Exit Pupil.

b) Long distance fire requires:

1. Large magnification to offset adverse light condition and concealment.
2. Maximum of light-gathering power.
3. Greatest freedom from loss of contrast.
4. It does, however, permit using a restricted exit pupil and a smaller field.

c) A compromise instrument is of necessity less effective for either type of fire and so should be used only for a reserve or emergency sight.

2. REQUIREMENTS

a. Optical Characteristics -

It is obvious that no one sight will possess all desirable properties. It follows therefore, that emphasis must be given to the most urgent needs of a tactical situation and a compromise reached within the optical limitations that exist. It is believed that the three following types of sight will best meet tank requirements -

1) Sight for close-in fighting (often on the move)

a) Low power (1 to 1.5x) hence little disturbed by motion
b) Large field of view (40o horizontal by 10° vertical) a minimum
c) Large or unrestricted exit pupil
d) Great eye relief (30 mm minimum, preferably unrestricted)
e) Easily visible open graticule

2) Sight for long Range - (Stationary fire)

a) High power (5 to 7x)
b) True field of 14° to 10°
c) Exit Pupil 7 to 7.5 mm
d) Minimum eye relief 22 mm (30 mm preferable)
e) Very fine line graticule, not obscuring crucial field, with provision for illumination.
f) This sight can be best made in periscopic form, and mounted with the low power sight above so that the gunner need not change body position when changing sights.

3) Reserve or compromise sight for use if the dual sight is destroyed.

a) Power 3 x to 4x
b) True field 20° to 15°

c) Exit pupil 7 to 7.5 mm
d) Minimum eye relief of 30 mm (40 mm preferable)
e) A rigid coaxially mounted telescopic sight with graticule adjustment for bore sighting is preferable.

b. General

1) Mechanical connection to gun which can be depended upon to maintain alignment under all operating conditions. This lies well within feasible mechanical tolerances and merely requires adequate design and construction.
2) Protection from dust, mud, rain, sleet and condensation.
3) Maximum freedom from veiling haze and maximum transmission.
4) Protection from glare by shades, sky vignettes, polarizing screens, color filters or other aids to retention of contrast.
5) At least two separate and reliable sighting units should be provided in each tank for following reasons:

   a) There may be loss of one sight by a direct hit which, both mounting and sight, preventing replacement.
   b) Advantage may be taken of two locations so that the simplicity and ruggedness of a coaxial mounting can be achieved in one location and the convenience and design advantage of a periscopic sight in another.

3. PRESENT SIGHTING EQUIPMENT

a. Periscopic Sight. Defects are, in order of importance

1) Inadequate linkage to gun

   a) Upper trunnion bearings of periscope holder are not of a type suited to the precision requirements and the manufacture is not held to close enough tolerances.
   b) Periscope holder is of a design which cannot provide adequate rigidity.
   c) Periscope holders bind in the cylindrical housing due to grit and abrasion. The clearances are too small, and the wiper is so placed as to retain dirt and grit where it will do most damage.
   d) Periscope itself of too flimsy construction.

2) The mounting of the sight within the general vision periscope introduces most of optical difficulties such as the following:

   a) The many unnecessary surfaces cause loss of transmission, scattering, flare, and veiling haze. These are aggravated by the entrance of dust, rain, etc.
   b) The front surface mirrors are inefficient in reflection.
   c) The ocular is so far removed from eye that poor field is inevitable.
   d) The diameter of the sight is necessarily so small as to further reduce the field.
   e) Interfering light enters the sight path from the side between the ocular and the eye causing further veiling haze and disturbing dark adaptation.
   f) It is difficult to reach the exit pupil, the guard is not suited to dual purposes and may limit lateral movements of the head.

3) Failure to meet the optical requirements of a close-in, long range, or compromise (reserve) sight.

   a) As a close-in sight its field is but 6° to 11° (depending upon type) whereas 40° is possible and desirable.
   b) As a long range sight its power, 1-1.8 is inadequate since 3x is minimum as a compromise and 5 to 7x is desirable.
   c) The exit pupil is too small for low light intensity and low contrast.

b. Coaxial Telescope (M50 Series). Its deficiencies are:

1) Placement - Present tanks are designed for the primary sight to be periscopic. On different models, placement of the coaxial telescope varies from awkward to impossible of access. Where it can be used--the time required to move the head from the general field periscope to the telescopic sight is too great to permit joint use.

2) Optical Design is Deficient. This sight is a compromise between the high power sight for stationary shooting (5 to 7 power, with 12° to 14° field) and the wide field low power sight for in-fighting, as such--its weaknesses are:

   a) Field is too small (12° 19' where it could be 20° for 3x power or 18° for 3.5x).
   b) The exit pupil too small for low contrast and light intensity (5.7 mm on the axis and diminishing rapidly off the axis).
   c) Sights exhibit excessive curvature of field--such that accurate assembly for infinity on axis makes it impossible to bring distant objects into focus in the zones required for fire at greater ranges.
   d) Focal setting varies for different portions of the exit pupil due to aberrations, outer portions being focused for near objects when the central portion is set for infinity.
   e) Veiling haze and flare are very bad, making the sight almost useless at low contrast and light intensity.
   f) Light transmission is low.
   g) There is no provision for cleaning or protecting the cover glass without removing the sight. Dust and mud are thrown on it in travel and dust is drawn onto the cover through the surrounding opening by the movement of air into the tank.

3) Optical Performance -

   a) Sights of the M50 series tested in the Laboratory have failed to exhibit the required resolving power (20 seconds arc for a 3x power).
   b) Assembly specifications ignore difficulties arising from curvature of field and other aberrations, making the effective focal setting for a near object. Such a setting prevents accommodative compensation. Only for a small pupil on axis can infinity be reached, otherwise negative accommodation would be required.

APPENDIX II

1. IMPROVEMENT IN PRESENT SIGHTING EQUIPMENT

a. **Mechanical Mounting and Linkage.**

1) Periscope Mounting

   a) Immediate steps should be taken to remove play in trunnion bearings--by closer tolerances and/or provision for take-up on sleeve.
   b) As soon as possible sleeve bearings should be replaced by precision pre-loaded ball races.
   c) More clearance should be provided between cylindrical surface of the periscope holder and casting with wiper filling entire space.

2) Coaxial telescope mounting should be revised so that the alignment adjustment is smooth and clamping does not disturb setting.

b. Optical Properties

Since many tanks will be equipped with the present types of sights, steps should be taken to assure the best possible function with the scope of the present type of design--as follows:

1) Establish manufacturing control and test, to assure proper adjustment, freedom from defective parts, and maintenance of a high standard of optical practice.
2) Make minor changes in optics to improve quality as tests may indicate.
3) Make provision for auxiliary devices such as dust protection and removal sun shade, sky filters, etc. for improving contrast detection.

2. DEVELOPMENT OF SUPERIOR SIGHTS

a. Dual Periscopic Sight

This sight adapts to tank requirements the type of optical system known to yeild the highest grade of performance. Enclosure Number 1 shows the general layout of the dual sight. It combines a simple "infinity" sight of unit power for infighting with 6 power prismatic sight for long-distance fire. Transition from the high magnification field to the unit power field is made by simply tilting the head 15°.

1) The "infinity" sight comprises:

   a) A right angle reflecting prism 2" high by 6-3/4" long.
   b) A partially reflecting plate set 52½° to the horizontal.
   c) A lens projecting an image of an illuminated graticule, at infinity thru the partially reflecting plate.

2) The prismatic sight comprises:

   a) A prism head using a portion of the same prism as above.
   b) A poro and a right angle prism complete the inversion.

c) The objective is mounted in a tube integral with the housing of the lower prisms.
d) A three-lens ocular is screwed into the same prism housing.
e) A chamber is attached to the left side of the prism housing to provide for introduction of filters, etc.
f) Lens curvatures are purely conventional. A system of this type yielding a 72° apparent field and excellent quality has been designed by Dr. Brian O'Brien's group Sec. D3 of N.D.R.C.
g) Mechanical features have been indicated only to show the practicability of the layout.
h) The offset of line of sight indicated is the same as in the present periscope M4. A decision on helmet design must be reached before this can be fixed but will not seriously affect the optical function.

b. Periscope Holder for Dual Sight

In order to mount the new Dual Sight in the present M4 tanks or others using the M4 periscope, a modified holder must be constructed. Enclosure Number 2 shows such a holder. It provides:

1) An opening 2¼" by 7" required by the dual sight.
2) Preloaded ball-races for trunnion bearings.
3) A strongly reinforced, rigid, cast body.
4) A solid oval ring-mount fitting the present opening in the turret.
5) A wide clearance between cylindrical surfaces to be filled by wiper.
6) Only salient features are shown, details are subject to revision in accordance with manufacturing considerations.

c. Coaxial Telescopic Sight

This sight embodies the properties recommended for the reserve or compromise sight.

Drawing Number 3 shows the approximate layout of such a sight.

1) In order to attain a wide apparent field (63°) special attention must be given the erector system. A photographic type anastigmat, relative apperture of f/2.8, gives results superior to conventional practice. Domestic types prove satisfactory.
2) A three-lens eyepiece of simple design gives good results and the two extra surfaces are not objectionable where blooming is used. (Curvatures indicated are purely conventional)
3) Mechanical features are only indicated in order to emphasize the greater diameters required, compared to the present M50 series-

    a) Ring mounts must be increased from 1-9/16" and 2-1/32 to 2½" and 3" respectively.
    b) Armor opening must be increased from 3/4" to 1" at the smallest and flared to 1-3/4" to preserve the full exit pupil 7 mm over the whole field.

4) A Laboratory mock-up of a sight of this character has been assembled of unrelated parts. This yields good results so that an integral design should be of excellent quality.

3. RELATION OF SIGHT TO TANK DESIGN

a. Mechanical requirements for mounting and linking of sights should be a primary consideration in tank design -

1) The main gun trunnion should be extended so as to provide ample room for coaxial mount and parallelogram linkage arm.
2) Gun shield should be extended so that telescope is not crowded against the recoil mechanism.
3) Space should be provided for link arm of greater length so that the requirements for precision of bearings are not so severe.
4) Shaping of the turret over the gunner's head so that the periscopic offset of line of sight can be reduced to 7" will improve the performance of the periscopic dual sight. The field of the unit power sight will be substantially increased and the light-gathering power for the field limits improved on the high power.

b. Posture requirements -

Placement of sights, controls and seats is a single problem requiring accurate knowledge and physiological data. A successful tank design requires reconciling these physiological requirements with the functional problems of mechanical design on the one hand, and the optical requirements of sight design on the other. The results have been in many cases, poor optical function and cramped posture which makes for poor coordination and early fatigue.

c. Influence on Optical Design -

1) Restrictions on opening in armor may reduce

   a) The effective size of the objective and so reduce either the magnification or the light gathering power or both.
   b) The field or the off-axis brightness.

2) Restriction on the diameter of the ring mount or periscope opening, tends at least to reduce the possible field.
3) Distance of eye to opening in armor often dictates the type of optics used and so the degree of excellence attainable. Greater distance above the optimum range leads to greater diameter of components and at the least to greater procurement difficulties.
4) If the fundamental design of tanks imposes such limitations on the placement of the gunner in respect to the trunnions as to require the use of a "broken" or hinged sight, added optical problems are created. A straight sight employs simpler optics and is intrinsically capable of giving better results. There are no inherent advantages to a hinged sight. Its purpose is to place the eyepiece in a fixed, convenient position. If satisfactory access to the sight can be provided for the gunner, and excessive movement of the eyepiece avoided (as is the case for the periscopic sight) there is then no advantage to be gained by use of a hinged sight. For a coaxial sight effort should be made to place the ocular as close to the trunnions as possible and to provide adequate space for the gunner to have access to it.

APPENDIX III

1. TECHNICAL TESTS TO SUPPLEMENT FIRING TESTS

The rigid technical requirements which must be fulfilled in order that sighting equipment prove serviceable, are not fully understood either by the manufacturers who have been pressed into service or by those concerned with the practical performance. Firing and use tests ultimately determine the utility of a device but generally fail to provide information of a specific technical nature by which the manufacturer may be guided in remedying any difficulties.

Such firing and use test should therefore be supplemented by quantitative technical tests -

a. Optical, to determine:

1) Resolving power, on and off the axis.
2) Veiling haze - flare images, etc.
3) Light transmission
4) Character of point image
5) Magnification
6) Exit pupil, on and off the axis
7) Distortion
8) Focal adjustment
9) Accuracy of graticule

b. Mechanical, to determine:

1) Alignment with bore at various elevations
2) Reproduceability and retention of alignment
3) Ease and accuracy of adjustment when bore-sighting
4) Resistance to shock and disturbing forces
5) Adequacy of engineering and manufacture

2. TECHNICAL INTERPRETATION OF PRACTICAL FIRE REQUIREMENTS

The practical needs in fire control may be evident to the officers and men engaged in firing tests and actual combat without their being able to translate their needs into specific optical or mechanical terms by which suitable design and modification of equipment can be accomplished. To achieve this it is necessary that someone with optical and mechanical training and experience be in continued and close contact with those carrying out practical tests. This individual should also receive complete data from combat experiences to make possible the translation of this information into design.

3. TECHNICAL LIAISON

Even when information from technical test and from contact with practical use and combat have been translated into the technical basis for modification of production and re-design, there can be no assurance of effective action. There must be free interchange of ideas with those responsible for design and development and close contact with the manufacturers. Such a liaison officer should represent the Armored Force officially.

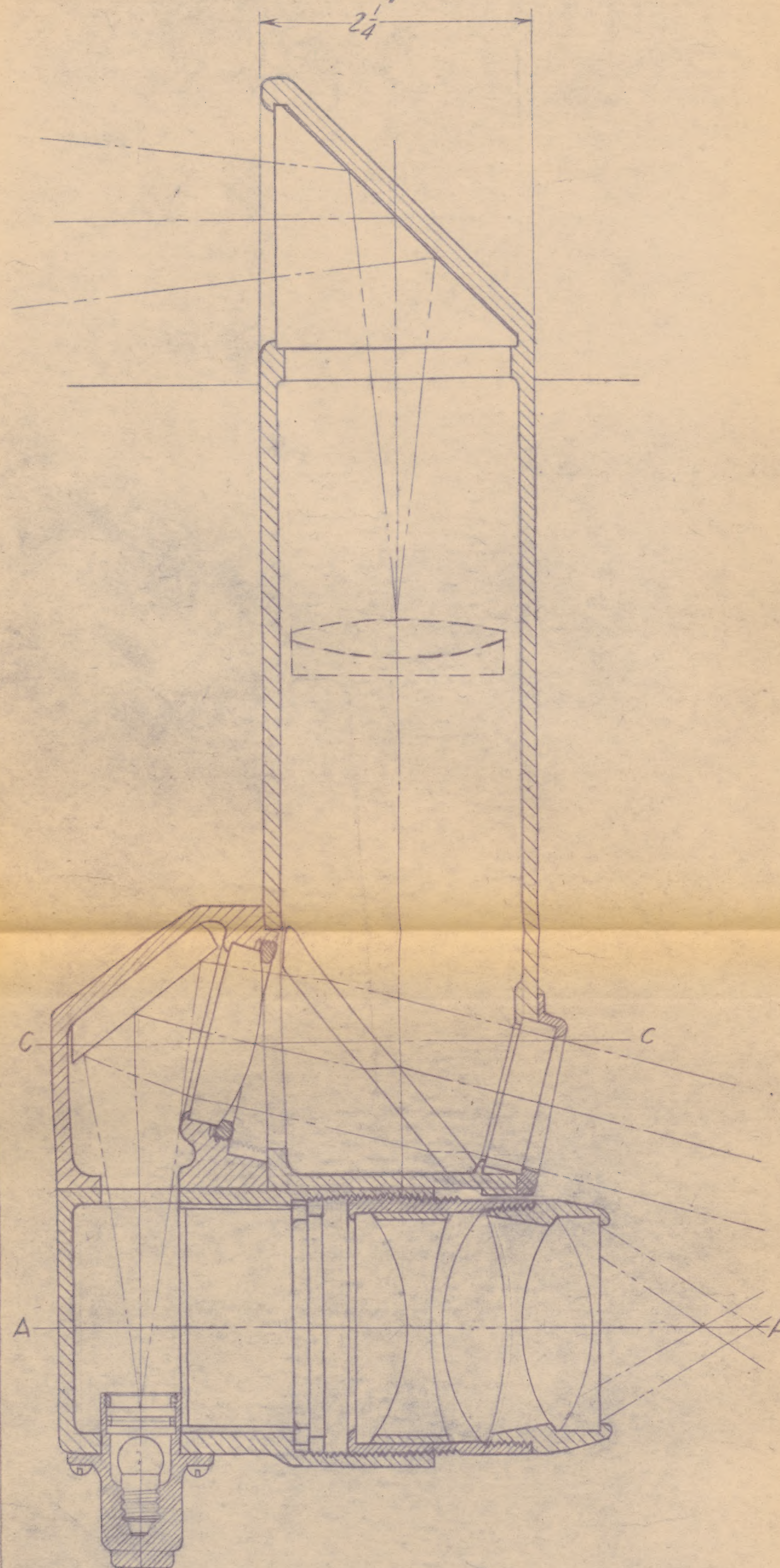
4. SUPPLEMENTING ORDNANCE DESIGN AND DEVELOPMENT

It has become evident that adapting artillery-type sights to tank use does not provide an adequate solution of our fire control needs. It is essential that the most advanced ideas of optical design be applied to our problems. Full use must be made of the best skill and technical facilities such as the National Defense Research Committee groups and the research staffs of manufacturers and laboratories. Coordination of such supplementary activities with those of Ordnance is essential to maintain complete understanding and achieve full use of all experience and facilities.

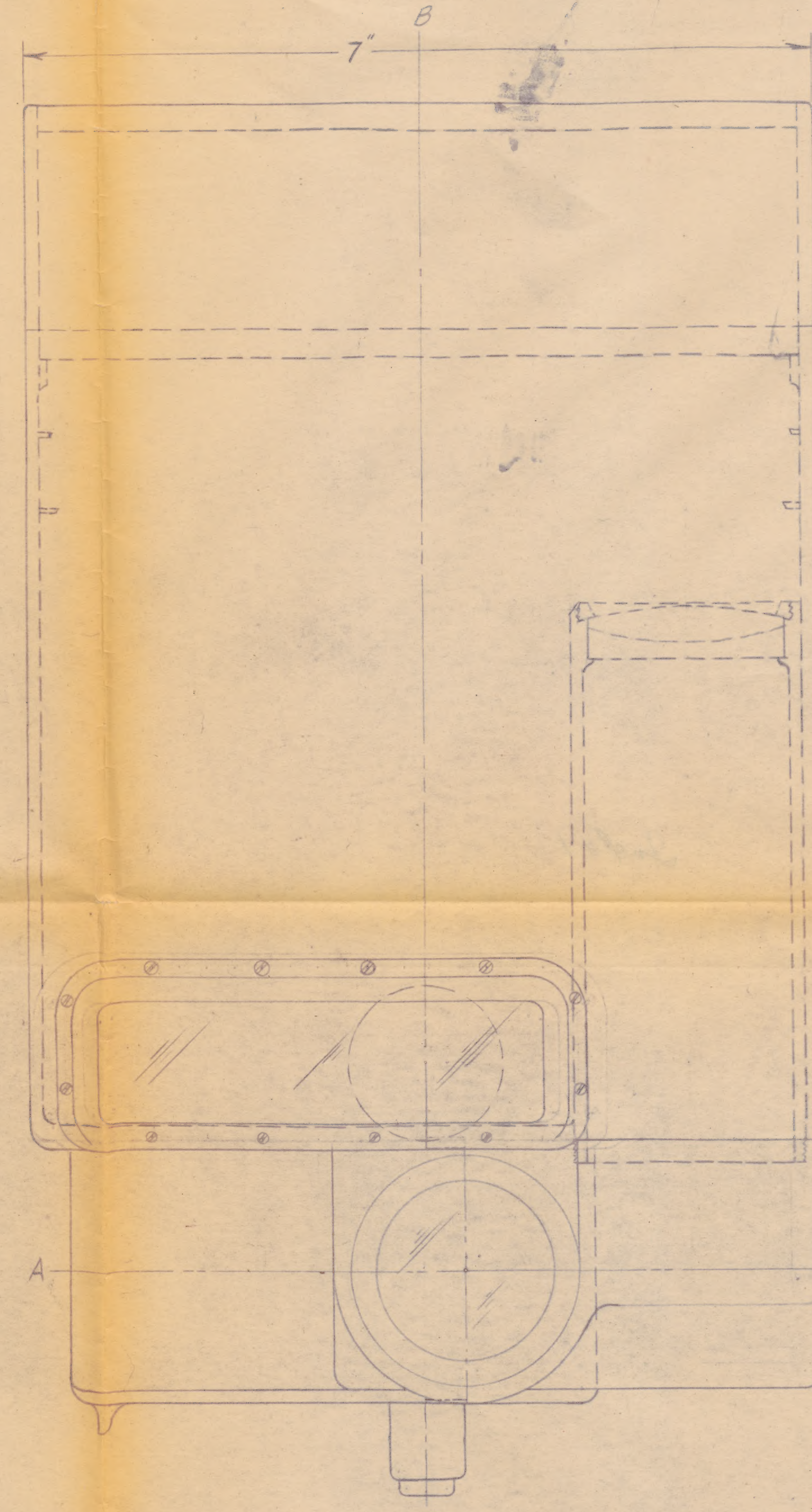
PERISCOPIC DUAL SIGHT

1. HIGH POWER
POWER x 6
TRUE FIELD 11°-40'
EXIT PUPIL 7 MM
EYE RELIEF 29 MM

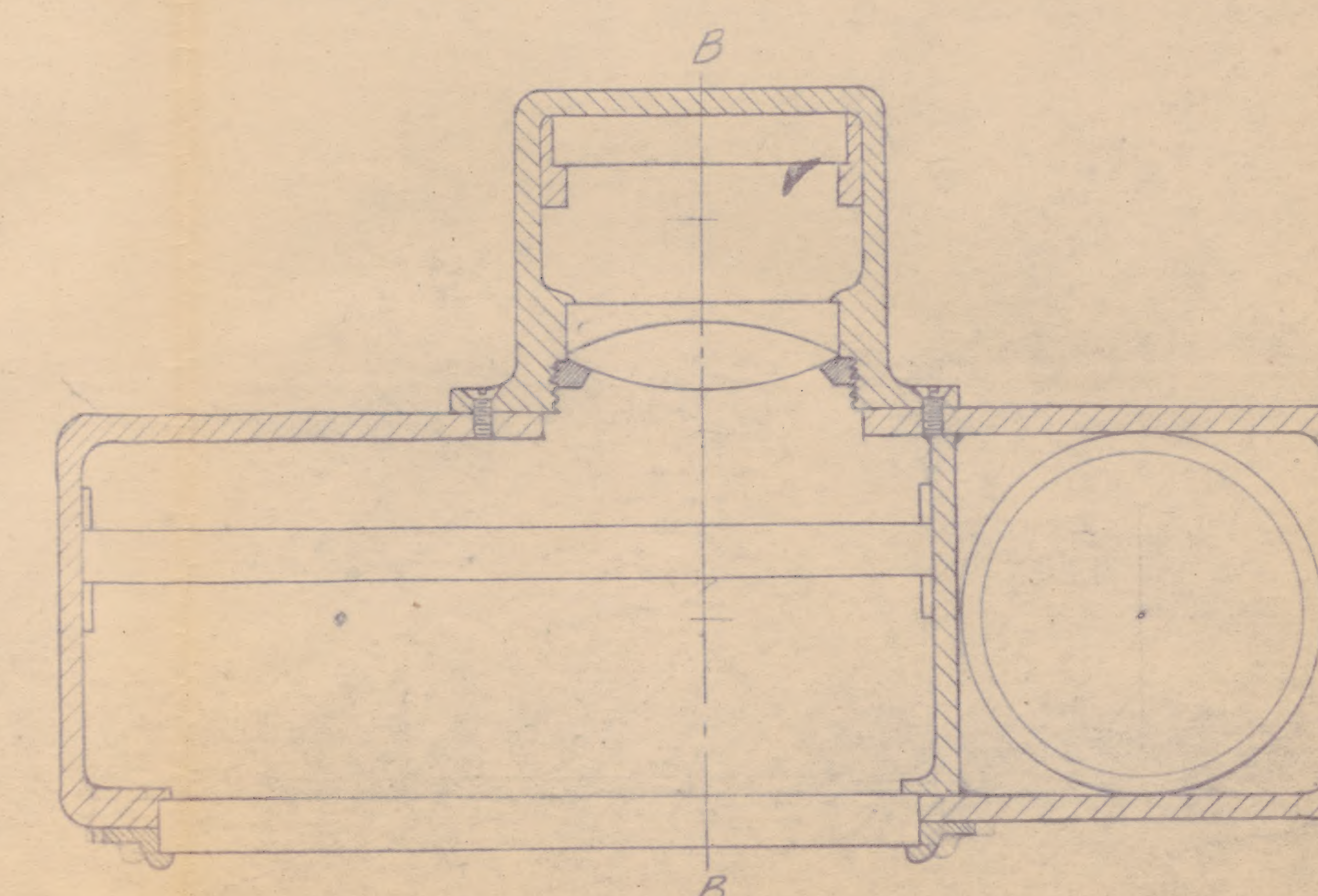
2. "INFINITY"
POWER x 1
FIELD - HORIZONTAL 45°
FIELD - VERTICAL 10°
EYE - UNRESTRICTED



SECTION B-B



PROFILE



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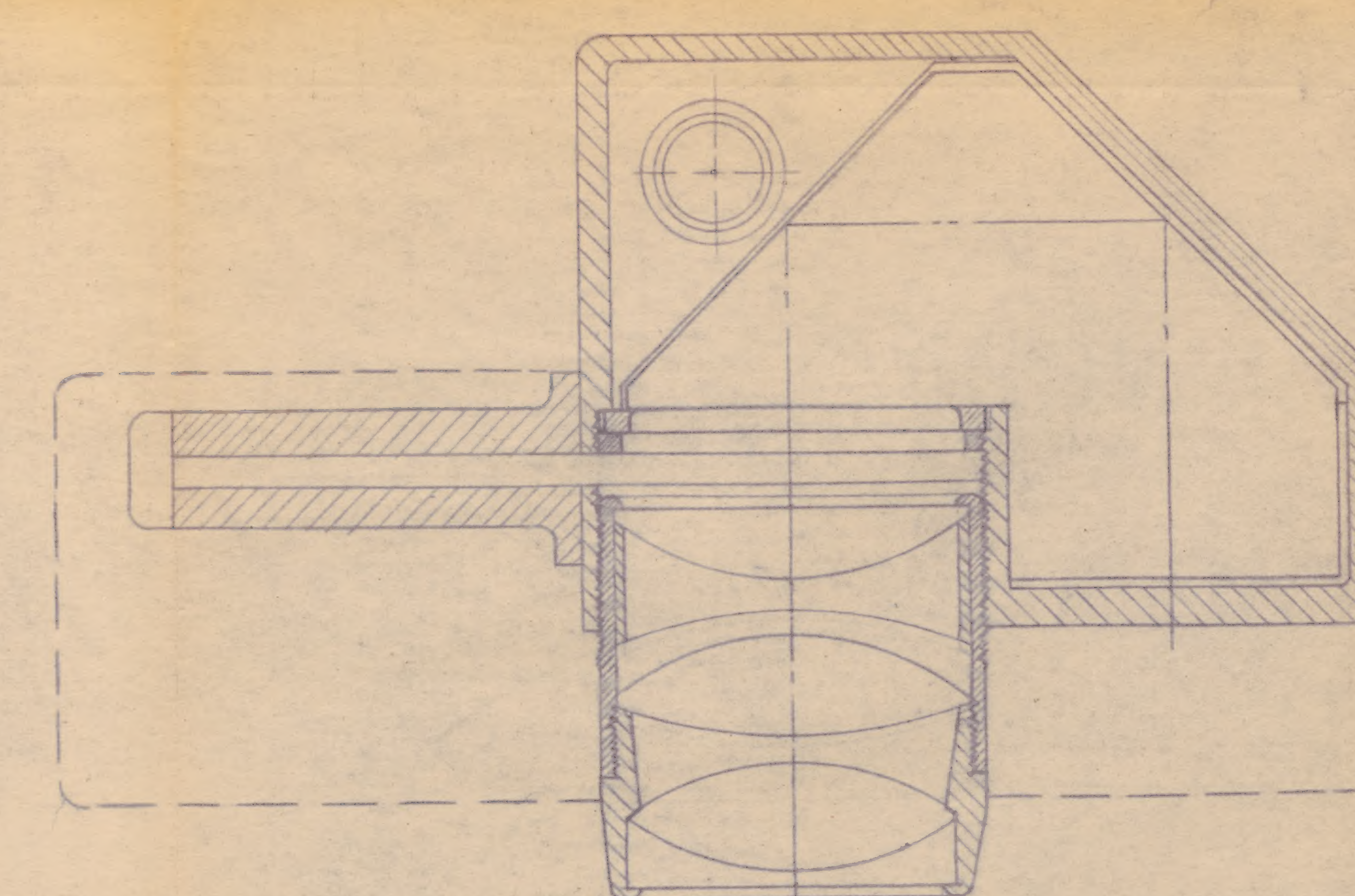


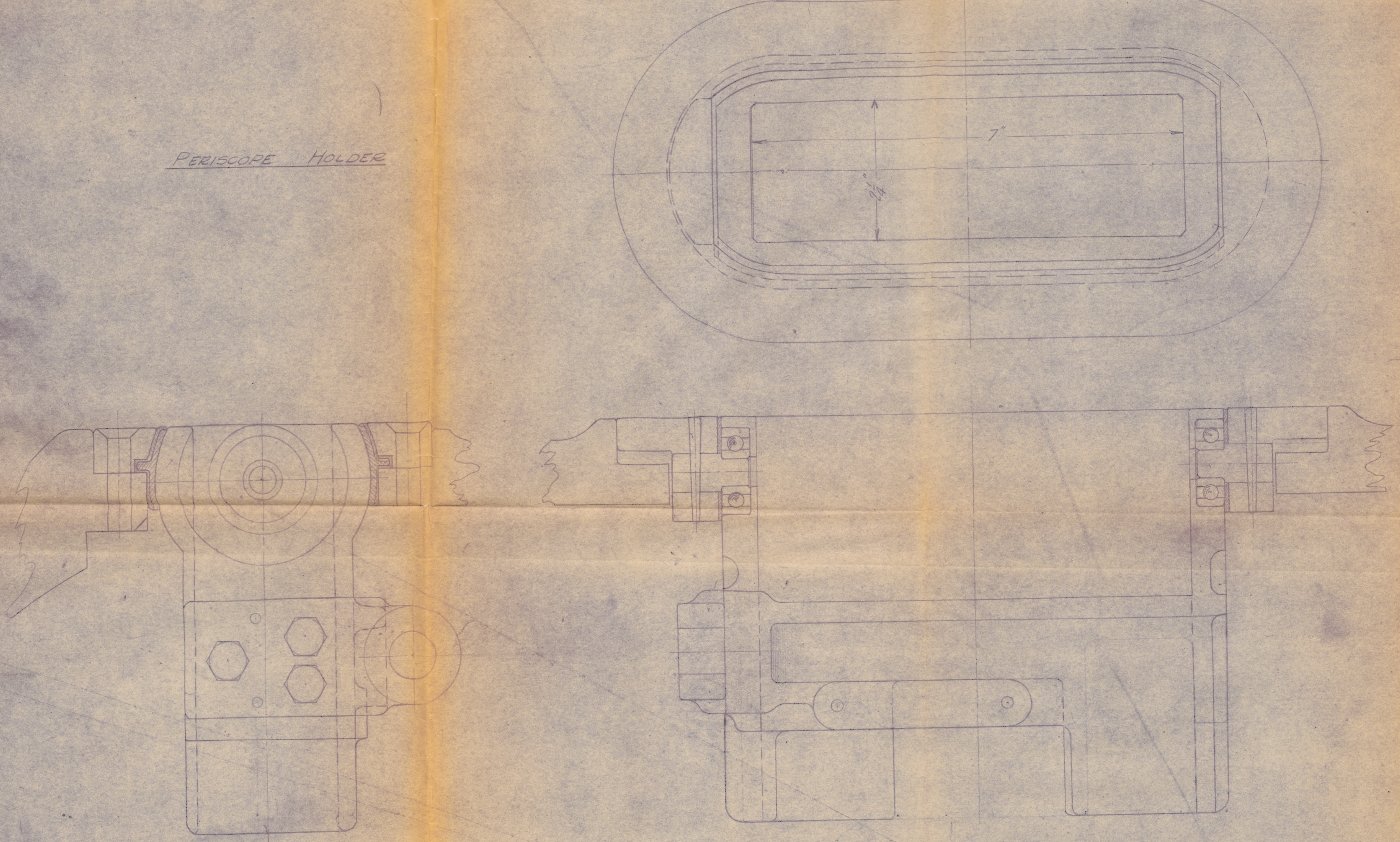
SECTION A-A

ARMORED FORCE MEDICAL RESEARCH LAB.

JAN. 20, 1943 F.S. BRACKETT

SCALE - FULL SIZE P. 6-1, 6-2, 6-4

PERISCOPE HOLDER



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SCALE - FULL SIZE

P6-1, 6-2, 6

P-9

TELESCOPIC SIGHT - M 51

POWER x 3.1
TRUE FIELD 12°
EXIT PUPIL 5.7 MM

TELESCOPIC SIGHT

POWER x 3.5
TRUE FIELD 18°
EXIT PUPIL 7 MM
EYE DIST. 32 MM

ARMORED FORCE MEDICAL RESEARCH LAB.

JAN. 21, 1943 F.S BRACKETT

SCALE - FULL SIZE

P 6-1, 6-2, 6-4